EU Environmental Technology Verification pilot programme

Statement of Verification

Technology:	Large Power PV Water Pumping System
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The verification process, the results of which are summarised in this Statement of Verification, complies with the **EU ETV General Verification Protocol 1.3** and with **ISO 14034:2016** Environmental Management - Environmental Technology Verification (ETV)

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Accreditation Mark

UKAS INSPECTION
4601

Type A
Inspection Body

Accredited to
ISO/IEC 17020:2012

BRE Global Verified ETV

Internet address where this Statement of Verification is available:
https://ec.europa.eu/environment/ecoap/etv

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1. Technology description

The Large Power PV Water Pumping System (LPPWPS) is a system for large-scale water pumping and irrigation powered solely by solar photovoltaics (PV) with no alternative power source such as grid connection, battery storage, or back-up generator. The system incorporates an innovative ‘Passing Cloud’ algorithm that assesses a number of system parameters in order to identify transient power drops that occur, for example, due to passing clouds momentarily shading the PV array. As a power drop that meets the specific passing cloud criteria is identified the system implements a custom set of operating instructions to mitigate the sudden drop in PV array power output and avoid abrupt pump shutdown.

By doing this the LPPWPS technology reduces the risk of damage to the pumping system from hydraulic shock (water hammer/fluid hammer) and to the electrical system due to sudden power fluctuations (overvoltage, surge current). Additionally, reducing the number of times the pump is stopped improves productivity in terms of the volume of water that can be pumped on a daily basis.

2. Application

2.1. Matrix

Large scale solar photovoltaic (PV) powered pumping and irrigation systems.

2.2. Purpose

Facilitate the use of solar PV as the sole means of powering large scale pumping and irrigation by reducing the risk of system damage caused by abrupt pump shutdown which may occur due to transient PV power drops caused by intermittent shading of the PV array (e.g. by passing clouds).

2.3. Conditions of operation and use

The LPPWPS is designed for a specific location and pumping/irrigation requirements. Once designed/installed and commissioned, the system must be operated and maintained in accordance with designer’s and manufacturer’s instructions.

2.4. Verification parameters summary

Parameters	Units
Performance parameters	
Passing clouds detected	#
Passing clouds avoided	#
Effectiveness of Passing Cloud algorithm	%
Operational parameters	
Installed solar PV capacity	kWp
Global/in-plane irradiance	W/m^2
Solar PV cell temperature	°C
Estimated PV power generation	kW
Inverter DC bus voltage	DCV
Variable Frequency Drive output	Hz
Pump run status	# (0 or 1)
Time	seconds
Environmental parameters	
Proportion of renewable electricity	%
Additional parameters	
The LPPWPS has a ROI of approximately 8 years	-

Table 1

3. Test and analysis design

3.1. Existing and new test data

Existing test data gathered by IES-UPM between 1 September 2017 and 31 August 2018 at the Villena site in Alicante, Spain, was used to verify the number of passing clouds detected and avoided and to establish the effectiveness of the Passing Cloud algorithm. No additional test data were required.

3.2. Laboratory or field conditions

Data were collected from the Villena site in Alicante, Spain.

Site Location:	Longitude -	0° 50' 32'' West
	Latitude -	38° 14' 19'' North
	Altitude -	593m

The solar PV array is sited in an area of flat open land which presents no obvious potential for shading of the PV array at any time of the day by objects such as trees or buildings.

Figure 1 – Photovoltaic (PV) array at Villena, 360kWp

3.3. Matrix compositions

The LPPWPS in Villena is configured in the following way:

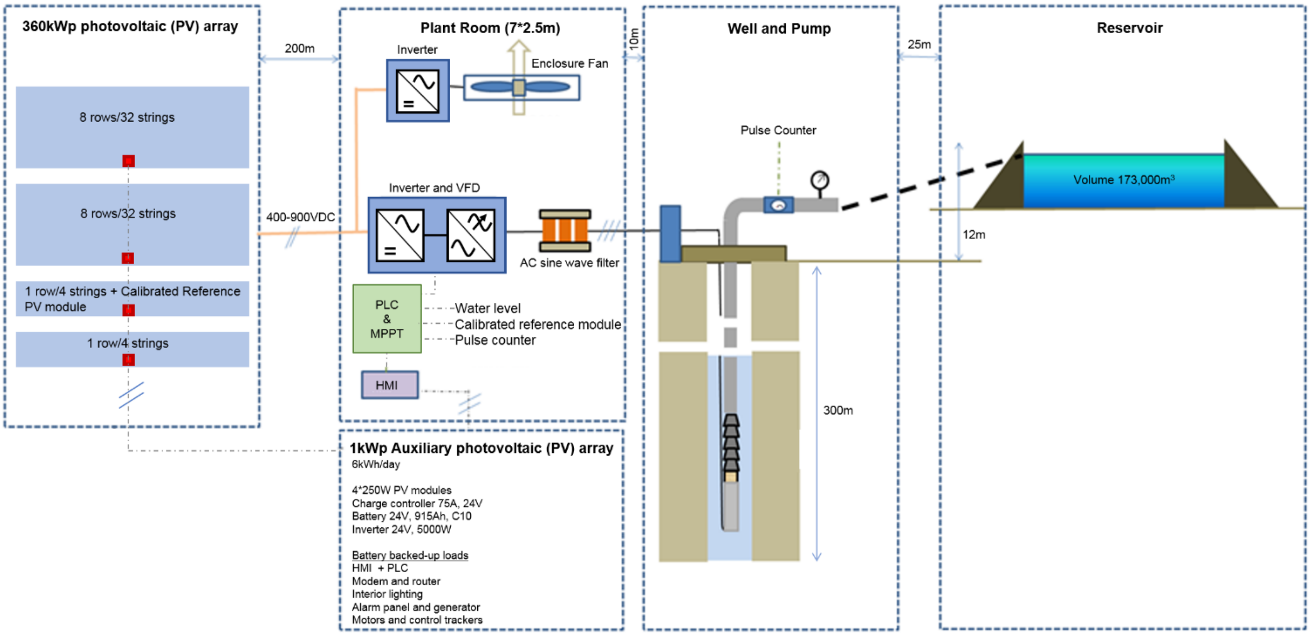

Figure 2 – System configuration at Villena

3.4. Test and analysis parameters

- Effectiveness of the Passing Cloud algorithm
- Villena site only
- 12 consecutive months of data

3.5. Tests and analysis methods summary

Additional testing was not required as sufficient data were available from the LPPWPS monitoring system which gathered data during normal system operation. These data were provided in Excel spreadsheet format and analysed by applying Excel formulae that replicated the Passing Cloud criteria shown below.

Passing Cloud criteria:

$G_{t0}>G_{min}$
$G_{t1}<dG_{t0}$
$G_{t3}\geq aG_{t0}$

Where:

- G = measured irradiance (W/m2)
- G_{min} = 400W/m2 (specific to Villena site)
- $_{t0}$ = 0-20 seconds
- $_{t1}$ = 21-40 seconds
- $_{t2}$ = 41-60 seconds
- $_{t3}$ = 61-80 seconds
- d = descent coefficient (0.5)
- a = ascent coefficient (0.8)

Passing cloud definition:

- The pump is running (i.e. ‘RUN = 1’)
- The estimated PV power is >130kW and inverter frequency >38Hz for a period of >60s.
- During G_{t0} the irradiance is $>G_{min}$ (e.g. 800W/m^2).
- During G_{t1} the irradiance decreases to $<0.5G_{t0}$ (e.g. 300W/m^2).
- During G_{t3} the irradiance increases to $\geq 0.8G_{t0}$ (e.g. 700W/m^2).

3.6. Parameters measured

- Irradiance (taken from the calibrated reference PV module)
- Cell temperature (taken from the calibrated reference PV module)
- Variable Frequency Drive output frequency
- Inverter DC bus voltage
- Time

n.b. Further system parameters were measured but these were not required for this verification.

4. Verification results (performance, operational and environmental parameters)

The 250kW submersible vertical electro-pump of the Large Power PV Water Pumping System (LPPWPS) situated in Villena, Spain, is powered solely by the 360kWp integrated/on-site solar photovoltaic system.

Over a period of 12 months, from 1 September 2017 to 31 August 2018, the patented Passing Cloud algorithm prevented pump shutdown on 494 out of 517 occasions where the passing cloud criteria were met.

Therefore, from 1 September 2017 to 31 August 2018 the passing cloud algorithm was 95.6% efficient.

$$\frac{494\ Passing\ Clouds\ Resisted}{517\ Passing\ Clouds\ detected} = 95.6\%\ efficient$$

<u>Performance parameters</u>

The effectiveness of the Passing Cloud algorithm was assessed by analysing data provided in Excel spreadsheet format. The data were recorded at 20 second intervals for a continuous 12-month period. Excel formulae that replicate the Passing Cloud formulae were written by BRE Global Limited and applied to the data.

Between 1 September 2017 and 31 August 2018, the Passing Cloud algorithm successfully resisted 494 passing clouds out of 517 detected.

<u>Passing clouds detected/avoided/not avoided</u>

Month/Year	Passing clouds detected	Passing clouds avoided	Passing clouds not avoided
September 2017	31	30	1
October 2017	28	27	1
November 2017	14	13	1
December 2017	17	16	1
January 2018	2	2	0
February 2018	18	17	1
March 2018	93	82	11
April 2018	96	92	4
May 2018	90	90	0
June 2018	49	47	2
July 2018	20	20	0
August 2018	59	58	1
Total	**517**	**494**	**23**

Table 2

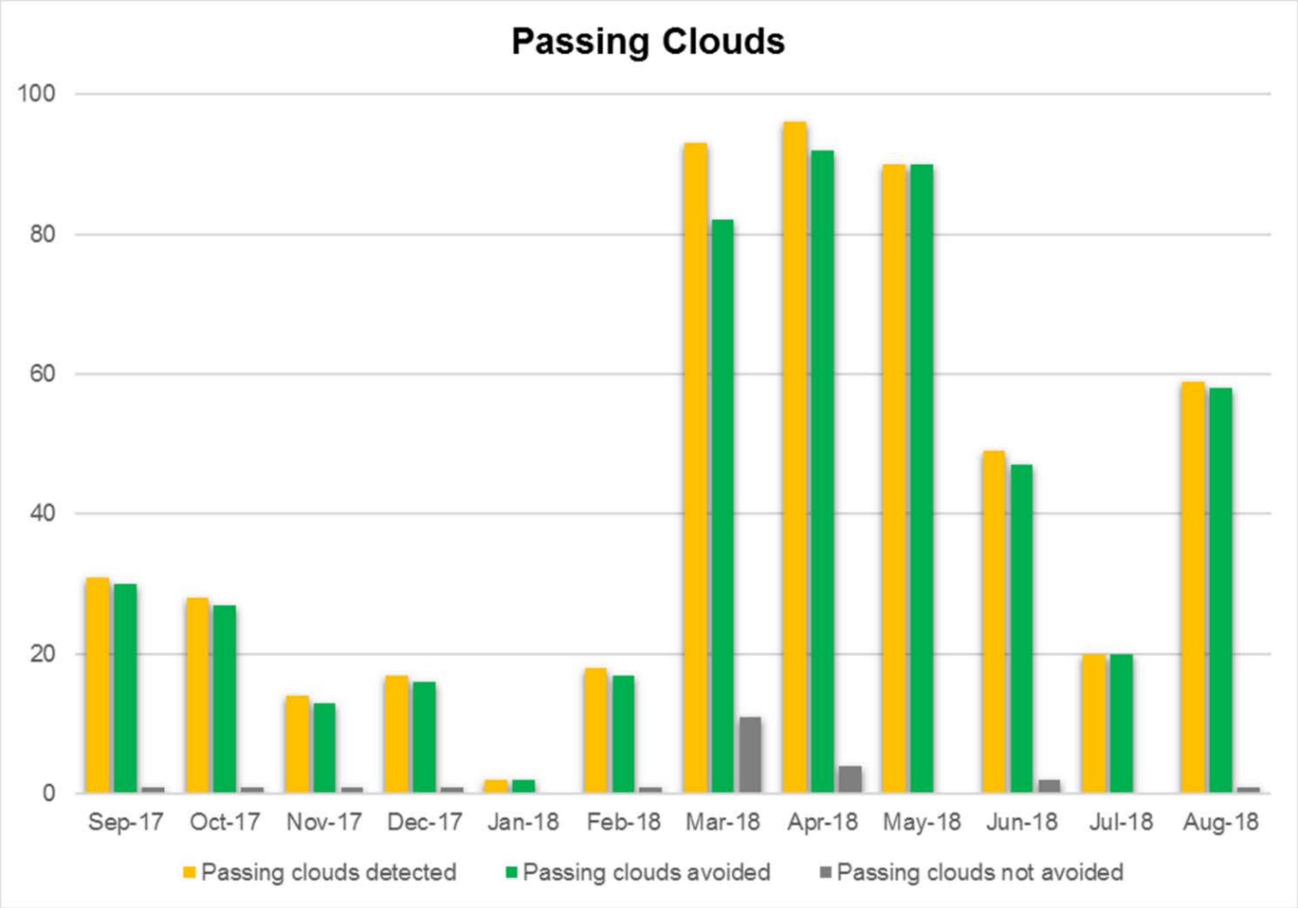

Figure 3

Operational parameters

Installed solar PV capacity – the installed solar PV modules are Martifer M Series 3R Plus 250Wp (at STC). There are 1,440 panels as seen in ***Figure 1***. Therefore, the PV array generation at standard test conditions (STC) is calculated to be 360kWp .

Global/in-plane irradiance - measured at the calibrated PV reference module and used in the estimation of PV generation. The irradiance is recorded in the Excel spreadsheet.

Solar PV cell temperature - measured at the calibrated PV reference module and used in the estimation of PV generation. The cell temperature is recorded in the Excel spreadsheet.

Estimated PV power generation – determined using the equation:

$$PM = PM^{*}\left(1 + \gamma(TC - TC^{*})\right)$$

Where: PM^{*} is the nominal power of the PV generator at standard test conditions[1]

γ is the temperature coefficient of the PV module

TC is the cell temperature of the calibrated PV reference module

TC^{*} is the PV module cell temperature at standard test conditions[1]

The estimated PV power generation is used to determine if the system should start, stop, or continue in its current mode.

[1] Standard Test Conditions (STC) as described in BS EN 61215-1:2016

Inverter DC bus voltage - this must be kept above 500VDC for the inverter to be able to provide enough Alternating Current (AC) output to the VFD to keep the pump running. The DC bus voltage is measured directly and recorded in the Excel spreadsheet.

Variable Frequency Drive (VFD) output - this will vary depending on the available input power from the inverter. The minimum frequency required by the 250kW submersible vertical electro-pump to pump water from the well is 38Hz. The VFD output is measured directly and recorded in the Excel spreadsheet.

Pump run status – this is either 0 (not running) or 1 (running) depending on the output from the VFD. The pump run status is recorded in the Excel spreadsheet.

Time – the various system component data loggers are read sequentially over 20 second periods. If the Stop algorithm is activated, the system will be stopped for 8 minutes. Starting the system takes 5-6 seconds. These times are evident in the Excel spreadsheet data which are presented in 20 second intervals.

Environmental parameters

A test system audit conducted on 6 November 2018 at the Villena site confirmed that the pumping system is powered solely by electricity generated by the 360kWp solar photovoltaic array. There is an additional 1kWp solar PV array on the roof of the plant room which is connected to battery storage and used exclusively to maintain power to the control system in the plant room.

5. Additional information, including additional parameters[2]

Minimising the number of occasions where the water pump stops abruptly will have a positive environmental impact through reducing wear and tear thereby prolonging the life of the pumping and electrical equipment.

The use of renewable energy is internationally recognized as being a positive way to address the global CO_2 issue. Specific environmental benefits and CO_2eq value have not been calculated as part of this verification.

Return on Investment was not calculated or verified as part of this verification.

It was not possible to operate the LPPWPS with the passing cloud algorithm deactivated so we were unable to obtain comparative data.

6. Quality assurance and deviations

This verification was conducted according to the documented procedures of BRE Global Limited. These procedures fall within the scope of BRE Global Limited's Schedule of Accreditation to ISO/IEC 17020:2012 issued by the United Kingdom Accreditation Service (UKAS). The verification process included independent internal and external review of the Specific Verification Protocol, Verification Report, and this Statement of Verification.

This Statement of Verification is valid only when presented alongside the Verification Report Ref No. IN20180147UK03E.

[2] with comments or caveats where appropriate